Comprehensive Lake Management Plan

For

Lake Noquebay

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Introduction & Setting

Lake Noquebay is a 2,406-acre drainage lake located in Marinette County, Wisconsin. It is the largest lake in the county and a popular tourist destination for fishing and motorized water sports. The privately held shoreline frontage is heavily developed with approximately 270 permanent and seasonal homes. The lake has three private resorts, a County owned park, swimming beach, and several boat landings. The State-owned Lake Noquebay Wildlife Area borders the lake to the east.

The purpose of this report is to develop a long-range sustainable plan for the management of aquatic plants in Lake Noquebay with an emphasis on: the control of variable-leaf watermilfoil (*Myriophyllum heterophyllum*); aquatic invasive species planning & prevention; and the preservation of sensitive areas and critical habitat.

Overview of Physical Characteristics of Lake Noquebay and its Watershed

Lake Noquebay is a hard water drainage lake with has light brown water of moderate transparency. A dam at the outlet maintains a head of approximately 3 feet during the summer months.

Although Lake Noquebay has a maximum depth of 52 feet, overall the lake is relatively shallow. Approximately 80 percent of the lake is less than 15 feet deep (Figure 1). Due to it's large size and shallow depth, the lake remains mixed throughout the year. Prolonged periods of calm hot weather can lead to stratification in deep basins of the lake.

Lake Noquebay's 86,500-acre watershed is located entirely in Marinette County. Approximately 46% of the watershed area is woodland and 30% is wetland. Agricultural land use makes up approximately 20,000 acres, or 23% of the watershed area.

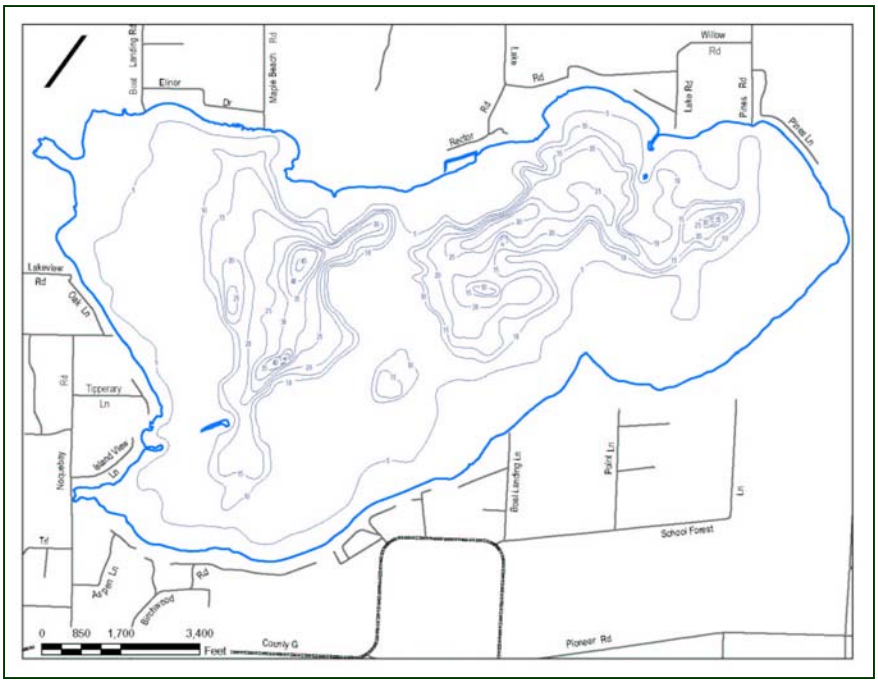


Figure 1. Lake Noquebay hydrographic map

Lake Noquebay Rehabilitation District

The Lake Noquebay Rehabilitation District (LNRD) was formed in 1975 to explore aquatic plant management options on the lake. Since 1978 the LNRD has overseen the annual harvest of aquatic plants from Lake Noquebay. The District has also worked cooperatively with Marinette County and the State of Wisconsin to operate and maintain a dam on the lake, to further characterize and track changes in water quality and aquatic macrophytes, and to manage runoff pollution sources in the lake's watershed.

History of Lake and Watershed Management Efforts

The LNRD, Marinette County Land & Water Conservation Division (LWCD) and Wisconsin DNR have a long history of protecting and improving Lake Noquebay's water quality. The earliest effort in 1964 was aimed at studying the incidence of swimmers itch and recommending control measures. In the early 70"s several studies explored the increasing aquatic plant population and set the stage for long-term plant harvesting, which continues to this day.

More recently, in 1995 Lake Noquebay was designated a priority watershed by the Wisconsin DNR for the control of runoff pollution in the lakes watershed. When the watershed project ended in 2006 most of the active farms in the watershed had participated in the effort leading to an estimated reduction in the phosphorus load of 1,052 lbs. annually.

As a result of the numerous studies and due to its status as one of the largest lakes in Northeast Wisconsin the DNR and LWCD have amassed a relatively large body of water quality data for Lake Noquebay. With the data collected as part of this planning effort there is now a 30-year history of water quality data for Lake Noquebay.

Public Access & Recreational Use

Lake Noquebay is one of the most important recreational resources in Marinette County. In addition to its draw as a fishing destination, Lake Noquebay is popular with water skiers, personal watercraft users and other motorboat operators. The lake is home to the Crivitz Ski Cats, an amateur water ski club that practices and performs on the lake.

The lake offers a wide variety of public and private recreational opportunities. There are currently four active resorts on the lake offering cabins, boat rentals, and swimming areas. Lake Noquebay County Park on the south shore offers a swimming beach, boat launch with parking, picnic and play areas, and an indoor pavilion. Public boating access is adequate with two improved landings, each with space for more than 25 vehicles and trailers. Three smaller landings offer small boat launching with limited roadside parking. In addition to the boat landings, walk in access is available at one other road right-of-way, at the dam, and in the State wildlife area.

Landowner Identification of Problems and Threats to Lake Noquebay

A survey of waterfront property owners and association members was conducted during the spring of 2008 to examine how people use Lake Noquebay, what they perceive to be the problems facing the lake, and to explore attitudes towards the harvesting program and other management actions.

The survey was mailed to all 428 LNRD member households at their official residences. A total of 228 surveys were completed and returned for a 53.2% return rate. No follow up correspondence was used to increase response rate. A complete listing of survey results can be found in Appendix A.

Lake Use Patterns

A series of questions was asked to try and determine some basic history of the respondents, their familiarity with Lake Noquebay, and how they use the flowage. A large majority of respondents (80%) owned water frontage on Lake Noquebay. A slight majority (55%) are weekend/vacation residents while a third are permanent residents. The average respondent has been living on or coming to the lake

for 29 years, the longest has been coming to Noquebay for 81 years. Respondents were also asked why they purchased property on Lake Noquebay. The top ranking reasons were proximity to the water (24%), beauty of the location (22%), boating (15%) and fishing (15%).

Perception of Water Quality Conditions & Fishing

The survey contained five questions designed to explore how landowners perceive the condition of Lake Noquebay and how conditions have changed over time. When asked about water clarity in the lake 66% had a favorable view. When asked about changes in water clarity 60% thought it has remained the same, 26% think clarity is improving and 11% think it is getting worse. Despite the favorable views regarding water clarity, more than half (52%) have an unfavorable view of the amount of algae in the lake and 35% think the amount of algae is increasing.

When the questions focus on aquatic plants the results are clear-cut. Nearly three quarters of the respondents felt the lake has too many aquatic plants and nearly half think the level of aquatic plant growth is increasing. Only 16% of respondents think aquatic plants are decreasing in Lake Noquebay.

On the question of fishing, 72% view the quality of fishing on the lake as favorable but nearly half think the quality of fishing is decreasing. Only 3% think fishing has been improving and 41% report there has been no change.

Asked about the severity of shoreline erosion on their individual lots, 32% report unfavorable levels of erosion. Only 13% report increased erosion on their shoreline while 60% report no change.

Issues of Concern

Respondents were asked to list the top three problems or concerns regarding Lake Noquebay (figure 2). Excessive aquatic plant growth topped the list with 27% choosing it as the top issue. Invasive aquatic species was second with 22% followed by failing septic systems at 16%.

A series of questions were also asked to further explore attitudes towards aquatic plants in Lake Noquebay. There was near unanimity in recognizing the importance of aquatic plants for fish and wildlife (91%). Still, when asked to consider the statement "Aquatic plants are only a nuisance when they interfere with boating and swimming", the split was close. 56% of respondents agreed with the statement and 41% disagreed. Similarly, 53% agreed that emergent plants such as bulrush and wild rice improve scenic beauty of the lake while 41% disagreed. Asked how aquatic plants impact their waterfront property, 64% reported that weeds washing up on their shore were a serious problem.

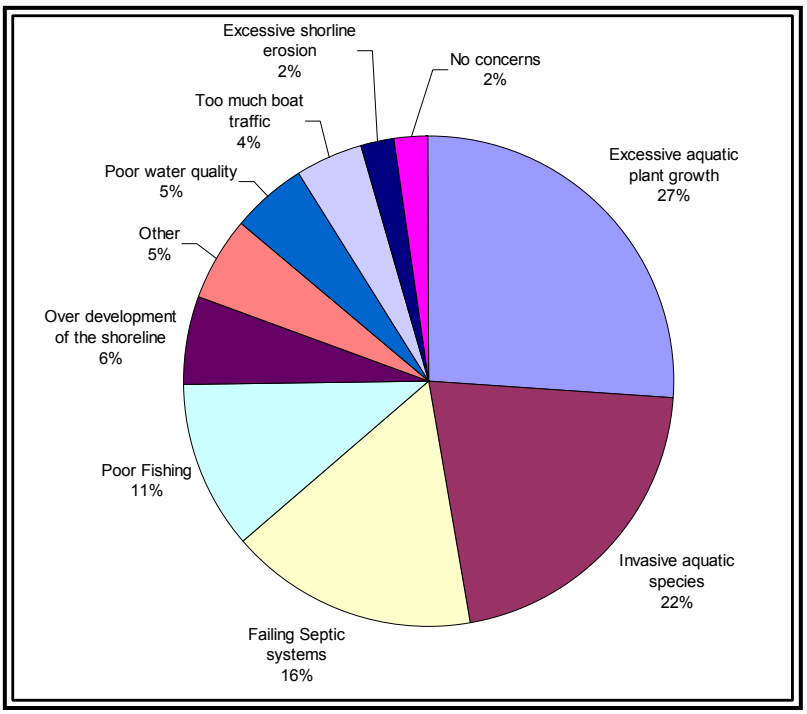


Figure 2. Top landowner concerns

Attitudes Toward LNRD Harvesting Program

In responses to questions about the existing aquatic plant harvesting program people are generally satisfied but feel more needs to be done in front of their home or cottage. A strong majority (66%) feels the harvesting program is effective or very effective at "Maintaining navigation and recreational potential on the lake". 23% think the harvesting program is somewhat ineffective and 5% feel it is ineffective. At the same time most of the respondents feel the harvesting program is less than effective in controlling plants in front of their property (48%) and in cleaning their shoreline in a timely manner (44%).

There were also some fairly strong opinions about modifying the harvesting program. A slim majority of respondents (56%) agreed "The level of aquatic plant harvesting needs to be increased". 36% disagreed. 63% of respondents think additional shoreline cleanup is needed and 60% think emergent plants (bulrush, wild rice etc.) and water lilies should be controlled.

Respondents were also asked to indicate areas that needed more aquatic plant control on a map of the lake. A compilation of the results can be seen in figure 3.

Aquatic Plant Control Alternatives

When asked about the need for alternative or additional plant control methods 60% agreed that harvesting is not enough and additional plant control measures are needed. However, when asked to identify which aquatic plant control measures they would support only harvesting received majority support with 88%. Biological controls and dredging received tepid support with 48% and 49% respectively. Chemical treatment was supported by only 39% of respondents with 44% opposed. Not surprisingly, 85% agreed that all lake users should share in the cost of managing aquatic plants on Lake Noquebay.

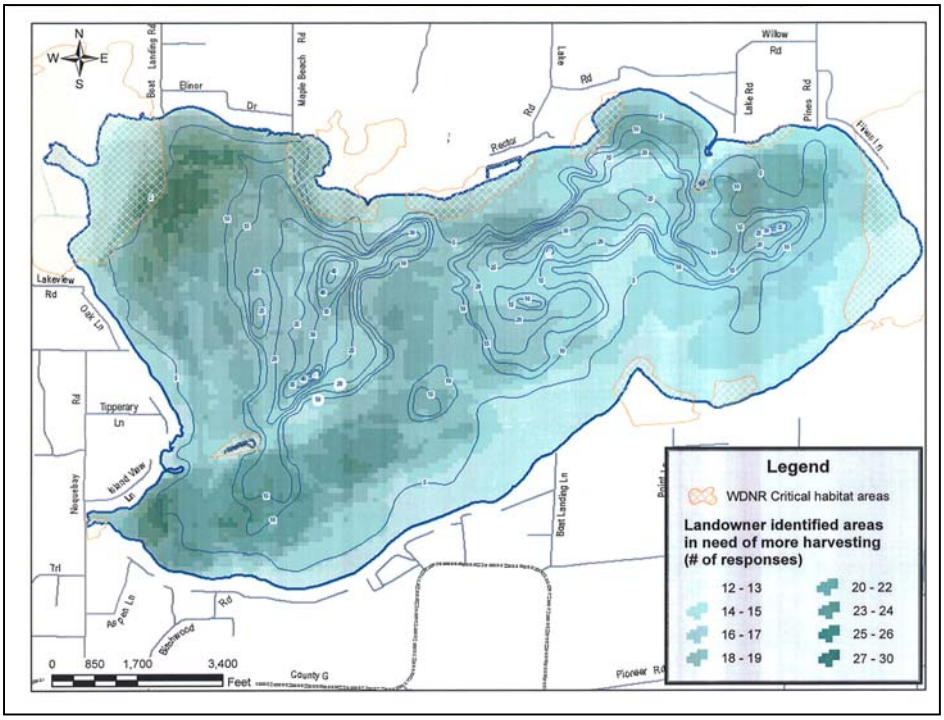


Figure 3. Areas identified by landowners as needing additional aquatic plant control.

Participation in Lake Organizations

According to the survey only 40% of respondents have attended an LNRD board meeting or annual meeting in the last three years. Nearly 60% haven't attended an LNRD meeting within the last five years and 38% have never attended a meeting. When asked if their should be a lake association to "promote, support, and participate in other activities to protect and improve Lake Noquebay" 83% said yes.

Support for other Lake Management Measures
Respondents were also asked several questions regarding activities and/or projects to protect and improve Lake Noquebay. Substantial majorities supported all of the suggestions that included; Aquatic invasive species monitoring (97%), Water quality monitoring (95%), Fish stocking (94%), Boat launch monitoring and aquatic invasive species education (94%), Supporting conservation measures to improve the lake (91%), Promoting policies and regulations to improve the lake (88%), Providing educational materials (82%), and Promoting community social events (66%).

Overview of Lake Noquebay Fish Community

As one of the largest lakes in northeast Wisconsin, Lake Noquebay is an important fishing destination. Known for its abundant panfish population, particularly bluegill, Lake Noquebay also supports a healthy population of bass, northern pike, and walleye. Musky are also present in the lake and brown trout can be found during the winter months.

Most of the panfish and gamefish in Lake Noquebay are sustained through natural reproduction. The DNR has stocked walleye in the past, most recently in 2005, and has been stocking about 1000 musky annually since 1990.

According to WDNR Fisheries Supervisor Michael Donofrio, fishing pressure on the lake is high but more than 70% of the catch is panfish, predominantly bluegill. On Lake Noquebay these higher harvest rates appear to be sustainable since fish surveys indicate high reproductive rates and a good size structure for bluegill and crappie.

Although much of the shoreline of Lake Noquebay is heavily developed the recently completed critical habitat designation report (Sabai 2009) did not note any obvious deficiencies in fish habitat. The report did identify several areas of critical habitat where alteration and disturbance should be limited to protect important habitat function and values.

Identification of Critical Habitat Areas

In 2006 the Wisconsin DNR, with assistance from the Marinette County LWCD, surveyed Lake Noquebay to identify areas of "critical habitat". The Critical Habitat Designation Program (CHD) was created to identify and provide protection for areas of lakes and streams that provide important fish and wildlife habitat, water quality protection, navigational routs, and natural scenic beauty.

Areas are designated as critical habitat if they have Public Rights Features, are Sensitive Areas, or both. Public rights features (defined in NR 1.06, Wis. Adm. Code) include the following:

- Fish and wildlife habitat;
- Physical features of lakes and streams that ensure protection of water quality;
- Reaches of bank, shore or bed that are predominantly natural in appearance;
- Navigation thoroughfares;
- Sensitive Areas, which are defined in Ch. NR 107 as: areas of aquatic vegetation identified by the department as offering critical or unique fish and wildlife habitat to the body of water.

Critical habitats are identified in the field and reviewed by DNR fisheries, wildlife and water resources staff. Data was also solicited from local units of government, conservation groups, federal agencies, and anyone who may have resource knowledge and information. The information was used to assemble maps to identify targets of focus related to fish, wildlife, endangered resources, and their habitats. Interestingly, when LNRD members were asked to identify "Areas of important habitat needing special attention in the management plan" they identified many of the same areas identified by the natural resource professionals (figure 4).

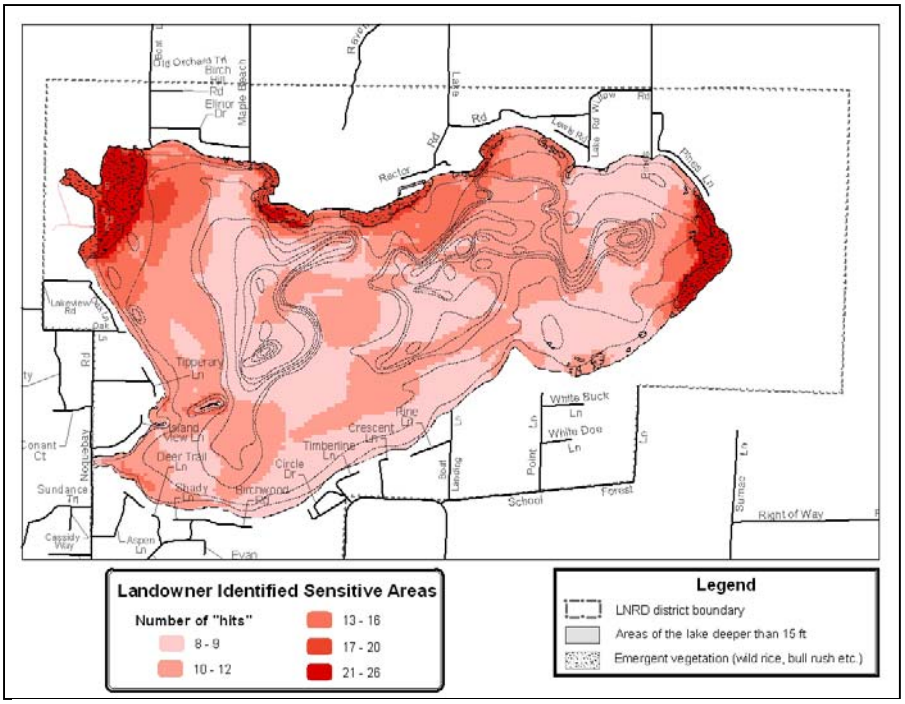
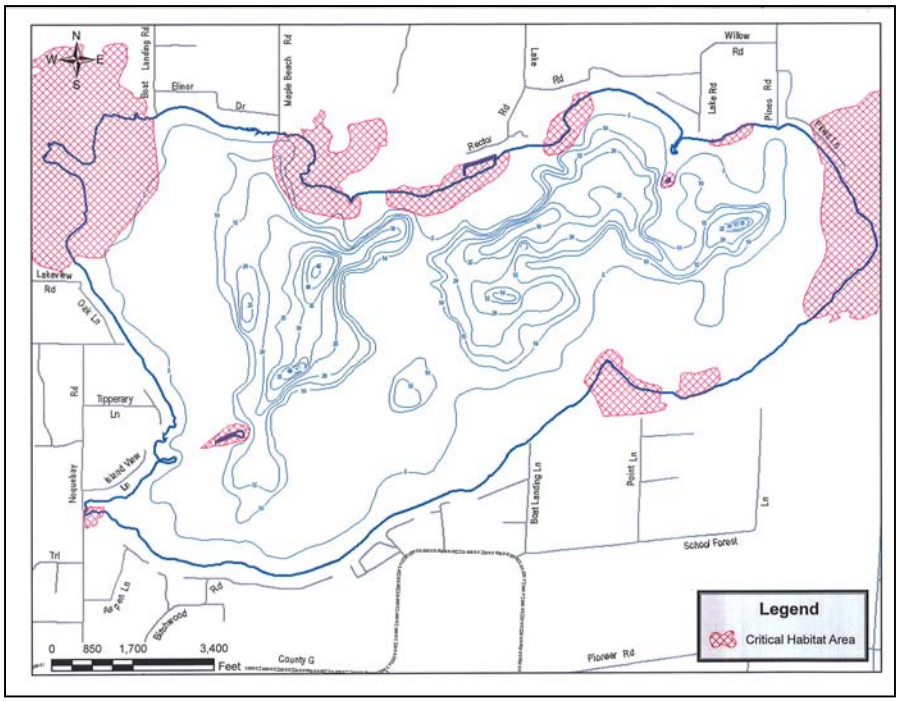


Figure 4. Landowner identified sensitive areas. Darker shading indicates more respondents identified the area as sensitive.

The Lake Noquebay Critical Habitat Designation Report was adopted in 2009 (Appendix B). Nine of the 11 areas were classified as critical habitat based on the presence of unique or important aquatic vegetation (figure 5) primarily stands of bulrush and wild rice, which provide critical spawning habitat and nursery areas for juvenile fish. Others include shallow marsh habitat with abundant floating leaf vegetation and/or high quality submersed plant communities with little various leaved milfoil.



While the critical habitat designations areas are designed to protect the important aquatic plant communities the recommendations allow for the harvesting of vegetation to maintain navigation to docks that may be within the CHD areas. Specific management recommendations are incorporated in the harvesting plan.

Figure 5. Wisconsin DNR critical habitat areas.

Water Quality Conditions

Water quality in Lake Noquebay was monitored in 2007 and 2008 following Wisconsin DNR water chemistry monitoring protocol. Water samples were collected from the surface and one meter from the bottom at the deepest part of the lake located on the west end of Lake Noquebay. Samples were analyzed for total and dissolved phosphorus as well as nitrogen series at spring turnover. Temperature, dissolved oxygen, pH, and conductivity were measured at one-meter intervals. A complete listing of water quality results can be found in Appendix C.

Temperature and mixing

Temperature and mixing are important since the frequency of mixing plays a role in dissolved oxygen concentration and internal nutrient cycling. Shallow lakes typically remain mixed throughout the year while deep lakes often stratify during the summer months. Summer stratification is a separation of the water into two distinct layers, a warmer top layer (epilimnion) and a much cooler bottom layer (hypolimnion). These two layers are separated by a transition zone (metalimnion), which anglers know as the thermocline. A difference in density prevents these two layers from mixing until fall when the surface temperature falls and equals the temperature of the hypolimnion.

Due to its relatively shallow depth and large surface area exposed to the wind, Lake Noquebay remains fairly well mixed throughout the summer months. Prolonged sunny windless periods can lead to temporary stratification in the deep basins but this condition is localized.

Dissolved Oxygen

Dissolved oxygen is vital for fish and most other aquatic life. When D.O. levels fall below 3 mg/l, sport fish species will not survive long. Few fish can tolerate D.O. levels below 2 mg/l. The amount of oxygen water can hold varies with temperature. Water at 33 degrees can hold approximately 14.2 mg/l while water at 75 degrees is saturated at 8.4 mg/l.

Dissolved oxygen comes from two sources, oxygen exchange with the atmosphere and oxygen production by aquatic plants and algae. Oxygen exchange with the atmosphere only occurs at the lake's surface. Plants and algae are found only to the depth of light penetration.

Since Lake Noquebay is relatively shallow it remains well mixed throughout the summer and the entire water column in areas less than 20 feet deep remains well oxygenated. Long-term monitoring indicates oxygen depletion below the 20-foot depth is common in deep areas during the months of July and August.

Nutrient Levels

Phosphorus and nitrogen are the two primary nutrients that regulate plant growth in a lake. When one of them is in short supply relative to the other it is the "limiting" nutrient. Increases in the limiting nutrient will lead to increased production in the form of plants and/or algae. Since nitrogen is water-soluble and can be absorbed from the atmosphere by some types of algae, it is typically found in abundance in lake water. Phosphorus, on the other hand, binds tightly to soil particles and is typically in short supply in lake water.

In Lake Noquebay the total nitrogen concentration in the spring of 2008 was 620 ug/l, which is average for lakes in Northeast Wisconsin. During the summer of 2007 and 2008 the average total phosphorus concentration was 22.2 ug/l, which is slightly below the statewide average for similar lakes (23 ug/l).

The ratio of nitrogen to phosphorus (N:P ratio) in Lake Noquebay was approximately 31:1 during the sampling period. Lakes with an N:P ratio greater than 10:1 are considered to be phosphorus limited. However, there has also been some research which points to nitrogen in the lake sediment being important for rooted aquatic plant growth.

As the limiting nutrient it is important to maintain low phosphorus levels in the lake. Generally, surface phosphorus levels should be maintained below 20 ug/l to prevent nuisance algae blooms and poor water clarity. Major sources of phosphorus include surface water runoff and groundwater inputs. All surface runoff will contain some phosphorus. However, it has been shown that the concentration of phosphorus in runoff from urban areas, agricultural land use, and even typical lakefront development will be much higher than if the same area were forested. Phosphorus enriched groundwater is typically the result of failing septic systems and/or systems discharging to the surface.

Water Clarity

Water clarity was measured with a Secchi disk, an 8 inch black and white disk that is lowered into the water until it disappears. This distance is the Secchi disk depth. Secchi disk depth is affected by naturally stained water, suspended sediment and algae growth.

Lake Noquebay has clear, slightly stained water. The slight brown staining is due to tannins, dissolved organic compounds released by leaves and needles as they decompose in wetlands within the lakes watershed. The average Secchi disk depth during the 2-year study period was 11.1 feet. Overall, the Secchi disk depth for Lake Noquebay is better than the statewide average for similar lakes and better than would be expected based on phosphorus levels. This due to the fact that Noquebay is dominated by rooted aquatic plants. The plants tie up most of the phosphorus, leaving little for the algae.

Chlorophyll-a

Chlorophyll-a is a pigment found in all green plants. The amount of chlorophyll-a is used as an indicator of the amount of algae in the water. The average chlorophyll-a concentration for the sample period was 3.5 ug/l. This level is quite low and indicates limited production of planktonic (free floating) algae. This level is well below the statewide average and, again, due to the abundance of rooted aquatic plants which tie up phosphorus, making it unavailable for algae production.

Trophic State

Secchi disk depth, phosphorus concentration and chlorophyll-a concentration are commonly used to calculate a lakes trophic state. Trophic state index (TSI) is a measure of the nutrient enrichment level of a lake. Oligotrophic lakes (**<40**) are nutrient poor, these lakes are unproductive and have very clear water. Eutrophic lakes (**>50**) have excessive nutrients. These lakes are very productive (able to grow lots of plants, fish and insects) and usually weedy, or support large algae blooms, or both. Mesotrophic lakes (**40-50**) have moderate nutrient levels and fall somewhere between the two extremes in aquatic plant and fish productivity.

Using phosphorus as an indicator the trophic state for Lake Noquebay during the study period was 51.7 which is in the low range of eutrophic, or nutrient rich. However, the Secchi TSI (42.5) and chlorophyll-a TSI (42.9) indicate the lake is in the lower mesotrophic range. The disparity in trophic state indices is not uncommon in shallow lakes that are dominated by aquatic plants. It indicates that rooted plants instead of algae take up most of the nutrients in the lake.

Water Quality Trends

Lakes are complicated and dynamic systems. Seasonal variations in water quality can confuse the data and make the detection of trends difficult if not impossible. Fortunately, there are 30-years of reliable water quality data for Lake Noquebay. This long history of water quality monitoring allows us to see through the "noise" of annual variability and identify trends in water quality.

A review of trophic state values for the period between 1979 and 2008 (Figure 6) show some clear trends. The Chlorophyll-a TSI value, which measures the concentration of free-floating algae in the water, has declined since 1979, indicating fewer algae in the lake. The Secchi TSI has also decreased slightly during the period, indicating that water clarity on Lake Noquebay has improved slightly over the last 30 years.

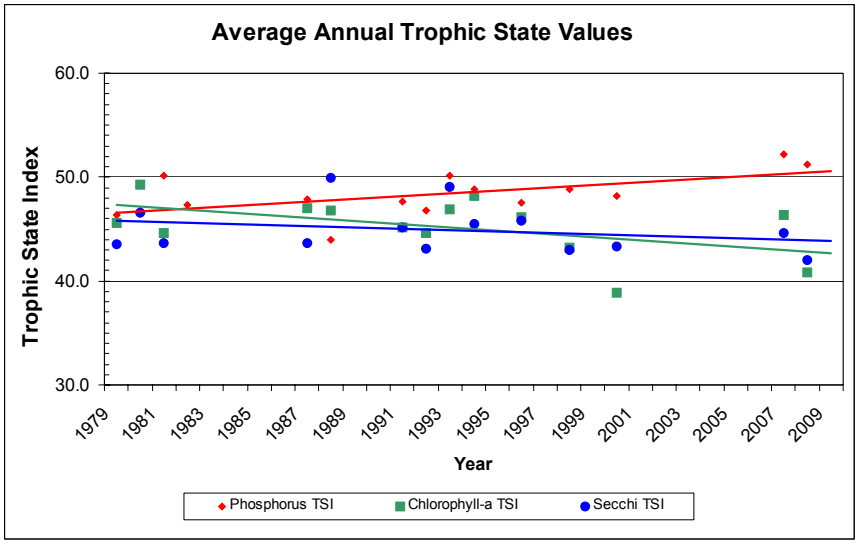


Figure 6. Lake Noquebay trophic state values.

While the Secchi and Chlorophyll TSI's indicate improving water quality, the phosphorus TSI has been steadily increasing over the last 30 years. A plot of all available phosphorus data for Lake Noquebay clearly shows an increase in the concentration of this important nutrient. This trend is seen when comparing both spring turnover and average summer phosphorus concentrations (figure 7).

Since phosphorus is the limiting nutrient in the lake its increase is troubling. Ordinarily an increase in phosphorus would lead to increased algae production and decreasing water clarity. However, the presence of zebra mussels (*drissena polymorpha*) in the lake is a confounding factor. The zebra mussel is an exotic freshwater mussel native to Europe. They attach to any hard surface and feed by filtering algae and small zooplankton from the water. Since its discovery in Lake Noquebay in 2006 zebra mussels have expanded greatly and can now be found attached to rocks, dock posts, the shells of native clams, and even the stems of aquatic plants.

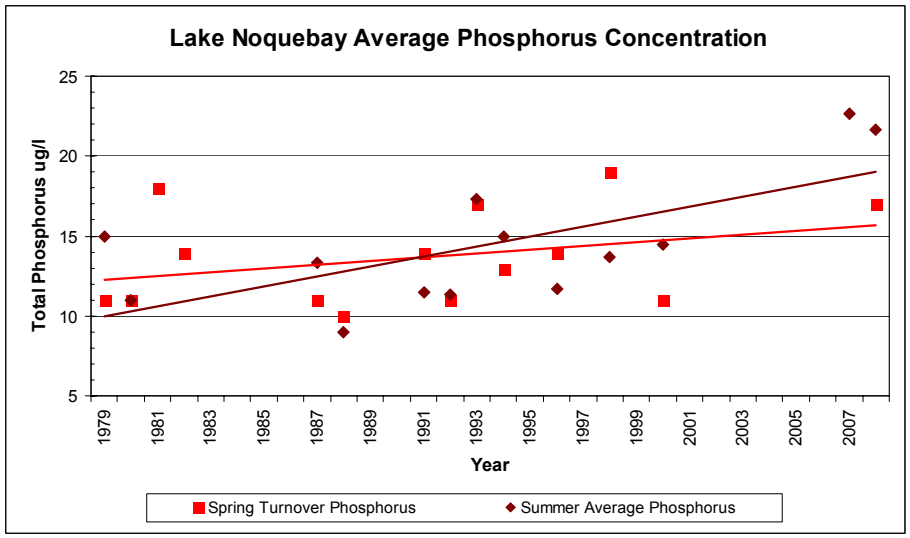


Figure 7. Average spring and summer phosphorus levels.

In the Great Lakes, where zebra mussels were first discovered they are responsible for improved water clarity and a resurgence of rooted aquatic plants. In Lake Noquebay they may also be playing an important role in suppressing algae populations and maintaining water clarity despite the increase in phosphorus.

Given their role in improving water clarity, it's tempting to look at zebra mussels as beneficial species. However, recent studies have linked zebra mussels to the increase in toxic blue-green algae (Raikow 2004) and other noxious filamentous forms of algae (Pillsbury, 2002). Both forms are unpalatable or unavailable to zebra mussels. Since they are at the base of the aquatic food web zebra mussels can also have negative effects on the rest of the lake ecosystem including fish communities as they also filter zooplankton from the water.

Phosphorus sources

While the monitoring has identified a notable increase in phosphorus concentration it does not identify the source. Sources of phosphorus include direct deposition, surface runoff, groundwater inputs, and internal loading. Internal phosphorus loading occurs when water overlying the sediment becomes anoxic (without oxygen) during periods of thermal stratification and reduced mixing. In deep lakes phosphorus is released from anoxic sediment below the thermocline and delivered to surface waters during spring and fall turnover. In shallow lakes, extremely dense plant growth and calm, hot weather can lead to stagnation and reduce circulation so much that anoxia can occur during the night when plants are using oxygen. This can result in phosphorus release from the sediment.

In Lake Noquebay thermal stratification is weak and the deep-water areas are small compared to the lakes volume so internal loading from deep sediment is unlikely. Significant phosphorus release from the sediment in shallow areas is also unlikely since most of the dense plant growth occurs in 5-12 feet of water where wind driven circulation is greatest.

At first glance increased phosphorus loading from agricultural areas seems unlikely. During the monitoring period the number of active farms in the watershed and acres under cultivation have declined considerably. In the last 15 years alone the number of active farms in the Lake Noquebay watershed have declined from 40 to 25. Also, most of the remaining farms have adopted best management practices to greatly reduce barnyard runoff and eliminate winter-spread manure. It is estimated that farms participating in the Lake Noquebay Priority Lake Project alone reduced annual phosphorus inputs to the watershed by 1,600 pounds and eliminated winter spreading of manure on more than 4,000 acres since 1995.

While agricultural inputs are declining, phosphorus inputs from residential development within the watershed are likely increasing. In recent years the number and the average size of new homes built on and around the lake has grown substantially. Numerous studies have reported that phosphorus loading from residential development is 4 to 8 times greater than forested areas. With high-density residential development, such as that found on the lakeshore, nutrient levels can exceed those from agricultural land use. The drastic increase is due to both increased phosphorus concentration in the runoff water and an increase in runoff volume due to impervious surfaces and compacted soils.

As the number and size of homes around the lake grows the phosphorus load from these areas increases substantially. Since the greatest increase in development has occurred close to the lake the likelihood of this runoff actually reaching the lake is very high.

Septic systems might also be responsible for increased phosphorus loading to the lake via shallow groundwater. Unfortunately groundwater inputs are difficult to estimate. Often a lake will have distinct areas of groundwater inflow and outflow. These patterns can be tracked through the use of piezometers, small temporary monitoring wells, located around the lake. Older septic systems, septic systems located in or close to the water table, and undersized systems are more likely to fail and export nutrients to the lake. Often systems that were adequate for a weekend cottage fail when the cottage is expanded or becomes a permanent residence.

During the priority watershed inventory it was estimated that 27% of the residences on Lake Noquebay were located on soils that are poorly suited to conventional septic systems due to high water table. While some of these residences have mound systems or holding tanks it is not known how many may be failing. While phosphorus typically binds tightly to soil particles, in its dissolved form it's more mobile and, with undersized and poorly maintained systems, the soils capacity to bind phosphorus can be overwhelmed. Failing septic systems can also discharge directly to the surface and run into the lake via surface runoff.

The recently introduced zebra mussels may also play a role in nutrient cycling in Lake Noquebay. Studies have shown that zebra mussels increase the cycling rate of phosphorus and other nutrients as they feed on algae and release soluble nutrients to the water column in the form of feces and psuedofeces. Increased nutrient cycling will be greatest during the summer months and could lead to even higher summer phosphorus concentrations.

Water Quality Protection Goals and Objectives

Despite the well documented increase in phosphorus levels, water clarity, and hence the perceived water quality in Lake Noquebay has remained very good. If the lakes water clarity is to be maintained the underlying phosphorus concentration needs to be controlled and ultimately reduced.

Goal: Reduce phosphorus concentration in Lake Noquebay to a level sufficient to maintain good water clarity.

Since every lake is unique it is difficult to predict the point at which increasing phosphorus concentration will lead to obvious reductions in water quality. With lakes such as Noquebay the search for an upper limit is confounded by the fact that shallow lakes have two stable states; aquatic plant dominated (clear water), or algae dominated (turbid water). A lake in the clear water state will tend to persist there as phosphorus levels rise well past the point where nuisance algae booms are possible. At some point the scales tip and the lake will quickly move into the turbid water state. Once in the turbid state negative feedback loops often drive even more nutrient release from unprotected sediment. Some new stressor such as a severe weather event, sudden surge in nutrients, or a disruption in the lake ecosystem brought about by invasive species often serves as a trigger to cause the shift in stable states.

Studies indicate that 25 ug/l seems to be the minimum phosphorus concentration needed to support high algae populations and maintain a lake in the turbid state (Moss 2003). Past this point, a shallow lake can persist in either state even as phosphorus levels reach100 ug/l or more! While nobody can say when a shift will take place, the chance that it will grows as phosphorus levels rise.

Experience shows it is very difficult, and expensive, to reverse the course and bring a lake back to the clear water state where aquatic plants can flourish. Given this fact, and recognizing the uncertainty in

predicting when a stable state shift will take place, it makes sense to err on the side of caution and maintain phosphorus concentrations below 25 ug/l.

Objective: Maintain summer total phosphorus concentrations in Lake Noquebay below 25 ug/l.

The latest monitoring effort revealed an average summer phosphorus concentration of 22.2 ug/l during 2007-2008. Data also shows a clear upward trend in phosphorus levels. It follows that action needs to be taken quickly to quantify phosphorus inputs and adopt measures to reduce inputs where possible.

While the LNRD benefits from 30 years of water quality monitoring, there has never been a nutrient budget calculated for the lake. A detailed nutrient budget would greatly improve the ability to focus nutrient reduction efforts for maximum benefit.

Target – Develop a detailed nutrient budget for Lake Noquebay to guide phosphorus reduction efforts.

Routine water quality monitoring is a necessary part of any nutrient reduction program. While changes in water quality are often difficult to detect in the short term, additional water quality data would be a valuable addition to the existing data set and could be used to track long-term trends and determine if management efforts are working.

Target – Monitor water quality on a regular basis to track changes and evaluate management efforts.

Water Quality Protection Alternatives

Phosphorus and other plant nutrients in a lake can come from both internal and external sources. Internal loading occurs when phosphorus is recycled from the sediment back into the water. In shallow lakes such as Noquebay internal loading is typically stable, or at least predictable, as long as aquatic plants dominate the ecosystem. Shallow lakes dominated by algae (turbid water state) can have wide swings in internal loading as the algae population booms and crashes throughout the year.

External phosphorus sources include runoff from within the lakes watershed, groundwater inputs, and direct deposition from the atmosphere. Some external phosphorus sources, such as runoff from forested lands, can be considered "background" loading and is not amenable to control. Other sources, particularly those elevated by changing land use practices, can be managed more easily.

The following practices can be used to reduce internal and/or external sources of phosphorus:

Phosphorus Inactivation
Sediment bound phosphorus can be inactivated through the addition of aluminum sulfate, or alum. This method is typically used to reduce internal loading in stratified (deep) lakes and in shallow turbid lakes where algae growth is suppressing the aquatic plant community. Alum works by binding tightly with phosphorus in the sediment and preventing it from moving into the overlying water column. Assuming external sources are well controlled, it is not unreasonable to expect an alum treatment to control phosphorus release for a period of 8-10 years after which it may have to be repeated.

Since rooted aquatic plants get most of their nutrients from the sediment, alum treatments have little effect on their growth. In fact, alum is typically used in shallow turbid lakes to reduce algae production and allow for the reestablishment of rooted plants.

Bass Lake in Marinette County was treated with alum in 1999 at a cost of $1,500.00 per acre. However, alum treatments must be tailored to each lake based on water chemistry, depth, and sediment phosphorus concentration so cost can vary considerably. Alum treatments require a permit from the Wisconsin.

Dredging

Dredging can be use to reduce internal phosphorus loading by physically removing highly enriched sediment. To be effective the underlying sediment must contain fewer nutrients. Additional "benefits" can be achieved if the increase in depth is sufficient to control plant growth by reducing light intensity.

Large-scale dredging is a very expensive management alternative, typically costing $10-$25 per cubic yard of sediment removed. Costs vary greatly depending on sediment type, dredge methods (hydraulic vs. mechanical) and available disposal options. State and federal permits are required for dredging.

Agricultural Nutrient Management

Nutrient management is an agricultural best management practice (BMP) designed to reduce nutrient inputs, and therefore nutrient runoff, to cropped fields while optimizing crop yields. Soil testing is conducted and a cropping plan is developed that best utilizes animal waste, crop inputs (i.e. nitrogen fixation by legumes), and commercial fertilizer to achieve realistic crop yields. Nutrient management planning is a cost-shareable practice under many state and federal programs and is typically required when cost-share funding is received for the construction of manure storage facilities.

In the Lake Noquebay watershed most farms are currently participating, or have participated in nutrient management planning. With current fertilizer and fuel costs it is in the farmers best economic interests to reduce outside nutrient inputs as much as possible.

Soil Conservation

Since phosphorus tightly binds to soil particles, reducing erosion from agricultural areas is key to reducing the nutrient concentrations in runoff. Soil conservation practices include source controls such as managing crop rotations and crop residue, contour cropping, and the planting of cover crops. Other practices such as vegetated waterways and sediment control basins are designed to trap pollutants before they enter perennial waters.

In the Noquebay watershed much of the highly erodable land has already been taken out of production for economic reasons as farms have gone out of business and cropland rental rates have fallen.

Animal Waste Management

Runoff from concentrated farm animals (barnyard runoff) and from winter-spread manure are two of the largest sources of agricultural runoff pollution. Best management practices to reduce animal waste runoff are primarily structural and include clean water diversion, barnyard runoff management, and animal waste storage. Manure storage in particular allows farm operators to more efficiently use manure for crop nutrients and further reduces outside fertilizer inputs on a farm.

The Lake Noquebay Priority Watershed Project was very successful at reducing both barnyard phosphorus runoff (110% of project goals) and winter-spread manure application (247% of goal).

The Lake Noquebay Priority Watershed Project reached 23% of its goal for upland soil loss and 119% of its goal for gully erosion. Although no longer available through the priority watershed project, other state and federal sources of funding are still available to address animal waste runoff and funding is actively sought by the Marinette County LWCD when animal waste runoff problems are identified.

Residential Runoff Management

Runoff from high-density suburban development, such as found around Lake Noquebay, can be a significant source of nutrients. Studies show that phosphorus yields from lawns are 8-10 times higher than from forested areas (WDNR, 2003) (Graczyk, 2003). Runoff volume also increases substantially as development increases. Managing residential runoff can be accomplished by controlling nutrient inputs at the source, and by trapping nutrient laden runoff before it reaches the lake. An effective program typically includes both source controls and nutrient trapping.

Impervious Surface Reduction

Studies show that phosphorus export rates are controlled primarily by runoff volume (Panuska, 1995) and volume increases greatly as the amount of impervious surface in the watershed increases. Research shows that converting only 10 – 20% of the land area in a watershed to impervious surfaces will double the runoff volume (Schueler, 1994). Impervious surfaces are those that absorb little if any runoff. These include rooftops, roads, patios, sidewalks, and any other hard surface. Even gravel driveways are considered impervious due to extreme compaction of the underlying soil.

Reducing, or preventing an increase, in the amount of impervious surface around a lake is an effective way to manage nutrient loads. Limiting impervious surface area is best accomplished through zoning but can also be addressed in educational programs. Some structures such as patios and driveways can also be installed using pervious pavers and other structural methods to increase infiltration.

Currently the Wisconsin DNR is proposing a change in the statewide shoreland zoning regulations that will limit the amount of impervious surface within 1000 feet of a lake to 30% of any lot. New development or expansion that would increase impervious surfaces to more than 20% of a lot would require mitigation to reduce the effects of impervious surfaces.

Nutrient Management

Studies clearly show that routine use of fertilizer on riparian lawns results in nutrient enriched runoff. The U.S. Geological Survey studied runoff from lawns under different management regimes and concluded that dissolved phosphorus concentration in regularly fertilized lawns was twice that for unfertilized and non-phosphorus fertilized lawns (Garn, 2002). Dissolved phosphorus is the least desirable form of the nutrient since it is immediately available to algae in its dissolved form. Reducing or eliminating fertilizer use, or switching to phosphorus-free fertilizer can greatly reduce the amount of phosphorus in runoff from riparian areas. Since phosphorus is rarely in short supply in our local soils lawn health does not typically suffer from the change.

Runoff Detention and Infiltration

When source controls are not feasible, the next best solution is to detain and infiltrate nutrient laden runoff before it can reach the lake. Several methods can be use including rain gardens, swales, detention basins, and shoreline buffers

Rain gardens are used primarily to infiltrate runoff from roofs. Typically roof runoff is collected and piped to a depression that is planted with species adapted for periodic flooding and wet soils. Runoff infiltrates and the plants absorb nutrients.

Swales are engineered ditches that are designed to slow runoff, provide for increased infiltration, and transport water to a planned discharge point. Often swales can be made to be inconspicuous. They are often combined with buffers and/or detention basins to increase infiltration and filtering. Where it is left intact, the natural ice-ridge berm that can be found on much of the lakeshore acts as a natural swale as it detains runoff before it reaches the lake.

Detention basins are designed to hold storm runoff for a specific period of time to allow for settling of sediment and other pollutants. Detention basins typically have an outlet structure that slowly releases stored runoff over a 24-48 hour period. Wet detention basins, which are designed to maintain a small permanent pool, are better at removing soluble pollutants than dry basins. Detention basins are most often used in commercial and industrial settings to remove nutrients from large parking lots and other intensive development.

Shoreline buffers are areas of grass or other dense vegetation designed to filter sediment and nutrients from runoff before it enters the lake. Buffer strips need to be at least 25 feet wide to function effectively although superior performance requires buffers at least 100 feet wide (Wagner, 2004). Buffers performance can be improved by shaping them to detain water and allow for increased infiltration.

With some creative design, buffers can be very aesthetically pleasing, often by using wildflowers and ornamental shrubs and incorporating them into a larger landscaping plan. For a more natural look, native species can be used. Native shoreline buffers also provide additional fish and wildlife habitat that is often in short supply on developed lakes.

Manage Septic Systems

All properties near Lake Noquebay are served by on-site septic systems. These are primarily conventional systems with a settling tank and leach bed, a mound system with settling tank, dosing chamber and leach bed, or holding tanks. Some of the older properties may have cesspool type systems with an open bottom tank.

The first step in managing septic systems on the lake would be to conduct an inventory of the existing systems. This requires working closely with the Marinette County Land Information Department that regulates private on-site sanitary systems. A study of shallow groundwater flow patterns would provide valuable information concerning septic system inputs and point out areas where septic system management is needed.

Even without a detailed survey there are basic practices that can be used to reduce the impact of septic systems. The first is routine inspection and pumping of the septic tank to remove accumulated solids. Currently every system installed since 1994 is required by state law to have their septic tank maintained (pumped and inspected) every three years. This mandate has recently been expanded and by October 2013 all septic systems will need to conduct routine maintenance. The Marinette County Land Information Department administers the septic system maintenance and inspection program.

Throughout Wisconsin most counties require septic systems to be inspected and failing systems replaced any time a property is sold. This is an efficient way of phasing out the old systems around many lakes. Unfortunately Marinette County does not require update at date of sale.

Lake and Watershed Management Recommendations to Protect Water Quality

Recommendations to protect water quality can be divided into three general categories. Monitoring and evaluation activities that will provide much needed information on which to make informed decisions; recommendations to reduce nutrient loading from the lakes watershed; and recommendations to reduce nutrient loading from riparian areas.

Recommendation #1 – Conduct a detailed study of nutrient loading to Lake Noquebay and develop a phosphorus budget for the lake.
A detailed phosphorus budget would be a valuable tool to help direct nutrient reduction efforts for maximum benefit. Completing a detailed budget requires monitoring nutrient inputs and flow on all of the lakes tributaries, monitoring nutrient export and flow at the outlet, and tracking in lake water quality and phosphorus release rates from the sediment. A complete budget will also track groundwater quality and flow direction to estimate septic inputs.

The Wisconsin Lake Management Planning Grant program provides cost-share assistance for lake management planning, monitoring projects, and other studies and assessments designed to understand lake ecosystems. Small-scale grants have a $3,000 limit while large-scale grants have a $10,000 limit. Both pay up to 75% of project costs.

Recommendation #2 – Inventory septic systems in the District and promote proper maintenance and replacement of failing systems.
The Marinette County Land Information Department permits septic systems and maintains septic system records. Good records exist for systems installed since 1980. Unfortunately records before that date provide little detailed information. As part of the expanded septic system maintenance and inspection program the Land Information Department will identify properties that have old septic systems and require that they be maintained and a licensed septic pumper or plumber submit records indicating they have been pumped or inspected and the tank is less than 1/3 full of sludge. While this effort will fill in many of the existing gaps in the data, and may lead to the obviously failing systems being replaced, it will not require that existing septic systems be inspected to ensure they are not discharging to the groundwater.

A detailed septic system inventory designed to identify all substandard systems would include a detailed inspection of the system and soils around the drainfield to determine if the system is discharging to the groundwater. Currently the LNRD cannot compel landowners to allow on-site septic system evaluations. Event he County needs to obtain an inspection warrant for entering private property if a landowner refuses an inspection request. Adopting sanitary district powers would allow the District to collect this information.

Recommendation #3 – Support a Marinette County ordinance requiring that all septic systems be inspected when properties are sold.
The LNRD should support efforts in Marinette County to enacting an ordinance requiring that septic systems be pumped and inspected by a certified plumber before a property is sold. Failing systems would have to be replaced, either by the seller or buyer, before the property transfer would be

allowed. Since the turnover rate is so high for recreational properties an update-at-sale ordinance would greatly increase the rate at which failing septic systems are replaced.

Recommendation #4 – Use phosphorus-free fertilizer in riparian areas.
Since phosphorus is the nutrient most responsible for excessive weed and algae growth, reducing its concentration in runoff will help maintain good water quality. It has long been recommended that urban and lakefront property owners severely restrict the application of phosphorus to lawns. As of April 1, 2010 Wisconsin will ban the application of fertilizer containing phosphorus to established lawns unless a soil test shows them to be phosphorus deficient. The new law also restricts the marketing of fertilizer containing phosphorus.

The LNRD should publicize the phosphorus ban and educate landowners regarding the effect of phosphorus on the lake and the reasons for the ban.

Recommendation #5 – Support efforts to limit impervious surface area in riparian areas.
The LNRD should support current State efforts to limit the amount of impervious surface allowed on lakefront properties. The changes proposed to NR 107 will slow, or even reverse, the increase in runoff volume and phosphorus reaching the lake from shoreline properties.

Recommendation #6 – Promote buffers, rain gardens, and other runoff infiltration measures.
Promoting the installation of practices to increase the infiltration of runoff will provide multiple benefits to the lake in the form of reduced nutrient loading and improved fish and wildlife habitat. Currently the Marinette County Land & Water Conservation Division has a limited amount of cost-share assistance for buffer installation. State and federal funding sources are often available as well.

Recommendation #7 – Reduce sources of concentrated animal waste runoff in the Lake Noquebay Watershed.
A majority of active farms in the Noquebay watershed have already taken steps to reduce or eliminate animal waste runoff from barnyards and stored manure. Most received cost-share assistance through the Lake Noquebay Priority Watershed Project. While the priority watershed has expired, Targeted Runoff Management (TRM) funding is still available throughout Marinette County. The TRM grant program is competitive, with funding going to projects based on water quality benefits.

The Marinette County LWCD continues to work with farms throughout the county to identify contaminated runoff issues and find funding sources to address the problems. The department will continue to stress reducing agricultural runoff pollution in the Lake Noquebay watershed.

Recommendation #8 – Eliminate winter spread manure in the Lake Noquebay watershed.
The amount of cropland in the Noquebay watershed receiving winter-spread manure has been reduced by more than 80% since 1995, primarily through the installation of manure storage facilities and adoption of the nutrient management planning by farm operators. Statewide, efforts to eliminate the application of manure to frozen or snow covered ground should be supported. Locally, the County LWCD should work with any new farms to install manure storage facilities and eliminate manure spreading in the winter.

Recommendation #9 – Conduct routine water quality monitoring on Lake Noquebay.
Tracking long-term water quality data is the only way to evaluate the success or failure of nutrient reduction efforts. The LNRD should collect water clarity measurements during the summer months every year and conduct routine water sampling to track nutrient levels in the lake.

Throughout Wisconsin volunteers measure water clarity weekly during the summer months. Water clarity is measured by lowering a special disk (Secchi Disk) into the water and recording the maximum depth at which it can be seen. Since clarity is the most common factor attributing to peoples definition of water "quality" it provides valuable information that the layperson can relate to. Persons interested in participating in this volunteer monitoring effort can receive equipment and training through the Citizens Water Quality Monitoring Network.

While volunteer Secchi disk data provides an important tool for tracking water clarity, it is not a substitute for routing chemical analysis. At a minimum water from the lakes surface and just above the bottom at the deepest part of the lake should be analyzed for total and dissolved phosphorus four times each year; at spring turnover, June, July, and August. Much valuable information can also be gained from a late winter sample and from testing for total nitrogen, nitrates, and ammonia. Typically dissolved oxygen and temperature profiles of the water column are also measured at these times.

While more data is always better, it may not be feasible to conduct monitoring every year. A good compromise would be to conduct monitoring every other year or even every third year. Cost share funding for water quality monitoring can often be obtained from the DNR through the Lake Management Planning Grant Program.